A NEW METHOD OF EVALUATING RHEOENCEPHALOGRAMS AND ITS APPLICATION IN THE STUDY OF VERTIGO

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16. Abstract

Eighty-seven healthy individuals were examined to determine their tolerance of cumulative coriolis acceleration. Forty-eight persons tolerated it well; the other 39 showed symptoms of vertigo (nausea, vomiting) at different times after commencement of stimulation. The rheoencephalograms obtained in the study were processed mathematically and analyzed by the "Minsk-22" computer; harmonic analysis involving use of Fourier trigonometric series was applied. Analysis of the most informative parameters of the 11 coefficients of expansion of the REG curves in the Fourier series by the computer yielded the integral parameter of vestibular apparatus stability. Considerable difference was noted in cerebral blood circulation between those subject to vertigo and those who are not, this difference appearing at the very outset of coriolis acceleration application, i.e., even before vertigo symptoms were exhibited.

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A NEW METHOD OF EVALUATING RHEOENCEPHALOGRAMS AND ITS APPLICATION IN THE STUDY OF VERTIGO

A. Ye. Kurashvili[1] and O. Ya. Plepis

The use of rheographic and rheoencephalographic methods makes it possible /49* to determine the quantitative and qualitative behavior of blood circulation in the region examined. It is also highly advantageous to apply them in study of the pathogenesis and effectiveness of treatment of various disease of the otorhinolaryngological organs.

Many authors have studied the effect of stimulation of the vestibular apparatus on cerebral circulation subjected to the action of angular and caloric stimulus (A. I. Naumenko, V. S. Olifov, 1959; G. M. Nummayev, 1969; V. S. Olifov, G. M. Nummayev, 1970), as well as to the action of g-loads and weightlessness (Yu. Ye. Moskalenko, 1967; V. V. Parin and coworkers, 1968; Yu. Ye. Moskalenko and coworkers, 1971).

In the present paper we wish to present out experience in application of a new method of evaluating rheoencephalographic data in study of the state of vertigo and prognosis of the latter.

Research Procedure

Study was made of 87 healthy individuals ranging in age from 18 to 30 years, 48 of whom withstood the action of coriolis acceleration with no unpleasant sensations whatever. These persons were classified as vertigo-immune and identified by index 0. The remaining 39 persons, in whom pronounced vestibulo-vegetative reactions (nausea, vomiting) occurred at various intervals after commencement of the influence of the vestibular stimulations, were classified in a second group and identified by index 1. The stimulation of the vestibular apparatus was caused by the action of coriolis forces applied in accordance with the technique of A. Ye. Kurashvili (1966) which consists in the following: the subject, seated in a chair rotating at a speed of 90° per

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*Numbers in the margin indicate pagination in the foreign text.

second, tilts his head towards the shoulders and straightens it up every 10 seconds as directed by the person conducting the experiment. The experiment lasts from 3 to 10 minutes, depending on the ability of the subject to endure the influence.

Rheographic sensors in the frontomastoidal abduction made it possible to obtain dynamic indices of cerebral circulation in the basin of the internal carotid arteries. To plot the rheoencephalograms (REG) use was made of a transistorized portable two-channel rheograph proposed by O. Ya. Plepis, with an operating frequency of 42 and 58 kHz, fastened on an electric-powered rotating chair. The recording device used was a five-channel "Orion" EKG-5-01 electrocardiograph which makes a photographic recording. Continuous recording was made of the REG curves for each subject before, during, and for 10 minutes after subjection to the coriolis acceleration. /50

At the present time there are two modes of analyzing the rheographic curves, the descriptive and the mathematical. The descriptive method of evaluating the REG curve is especially subjective; it takes into account the nature of ascent of the wave, the shape of the peak, the height of the wave, the nature of the descending portion of the curve (depression of the incisura, appearance or disappearance of additional waves).

The mathematical method of evaluation basically takes into account certain amplitude (height of the REG curve and incisura) or time indices (time of ascent and descent of the rheographic wave, etc.).

The significance and clinical interpretation of these indices have been dealt with in papers by a number of authors (Jenkner, 1957, 1962; A. M. Veyn and M. A. Ronkin, 1962; Kh. Kh. Yarullin, 1967; Yu. Ye. Moskalenko and co-workers, 1971). All these methods of processing REG curves are time-consuming, however, and do not permit extraction of the maximum of useful information from them.

In order to make a quantitative evaluation and determine the characteristics of the shape of the rheographic curve we employed the harmonic analysis method involving the use of a Fourier trigonometric series. By this method any curve

of complex form which recurs periodically can be broken down into a series of simple harmonics determined by Bessel formulas (N. Ya. Vilenkin, 1965).

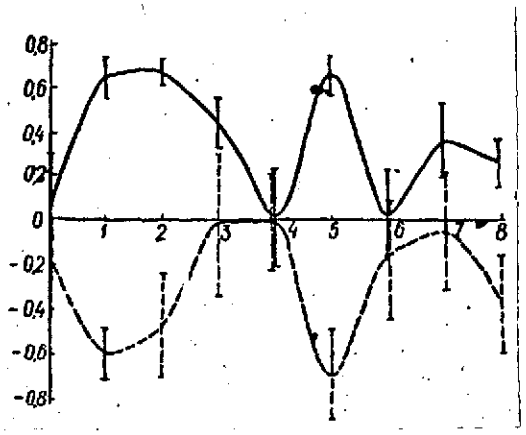

Figure. Integral Parameter of Stability of Human Subjects to Vertigo, Based on Rheoencephalographic Data. The value of the parameter from +1.0 to -1.0 is marked off on the Y-axis, and the time of the experiments on the X-axis. Notation: 0, initial state; 1, 2, 3, at first, third, and fifth minute of subjection to influence of coriolis acceleration; 4, examination immediately after cessation of influence; 5, 6, 7, 8, investigation at third, fifth, seventh and tenth minutes after vestibular stimulation. The solid-line curve denotes stability toward vestibular stimulation, and the broken line instability toward vestibular stimulation.

Inasmuch as the rheoencephalogram is not a harmonic curve, provision was made for normalizing it by means of the compressibility factor in accordance with the formula $T \cdot \alpha = 1$, where T is the length of the REG curve and α the compressibility factor.

Five REG curves of each nine recording cycles (initial, at first, third and fifth minutes of action of the coriolis acceleration, and at the first, third, fifth, seventh, and tenth minutes after subjection to the influence) were plotted for each of the subjects, by the following procedure; the amplitude of each REG curve was determined in mm at intervals of 0.02 second for the duration of 1 cardiac cycle. The numerical values obtained were transferred to punch tape and introduced into a "Minsk-22" computer according to an assigned algorithm. The computer determined 11 Fourier coefficients for each subject. The coefficients obtained were then averaged by group. The dispersion of these coefficients was simultaneously evaluated. In order to obtain the integral parameter of stability of the vestibular apparatus toward the action of coriolis acceleration, a subroutine using the following decision procedure was introduced into the computer:

$$\sum_{j=0}^{9}\sum_{i=1}^{n} Pij\ sign\ \{aij-\bar{\bar{a}}ij\}$$

where ΣΣ is the weighted sum of the Fourier coefficients, j are the examination cycles from 0.1-2..., to 8, i is the number of Fourier coefficients from 0.1, 2..., to n, P is the weighting factor, the role of which amounts to emphasizing the significant and suppressing the less significant Fourier coefficient; sign{} is the sign of the figure obtained in braces; $\bar{\bar{a}}i$ are the Fourier coefficients; $aij-\bar{\bar{a}}ij$ is the difference between each coefficient and its threshold value.

Results of Experiment and Discussion /51

Analysis of the most informative parameters of the 11 coefficients of expansion of the REG curve into a Fourier series performed by the "Minsk-22" computer yielded the integral parameter of stability of the vestibular apparatus. A graphic presentation of the index obtained on the basis of the experimental cycles and vestibular apparatus stability groups is given in the accompanying drawing. In this graph the curve characterizing the integral parameter of vestibular apparatus stability is represented by a solid line and is situated above the abscissa line, being conditionally assigned a plus sign. The integral parameter of instability toward vertigo, in the form of a broken line, is situated below the abscissa line and has been conditionally assigned a minus sign. The curves themselves are in opposite phase relative to each other. The integral time parameter is oscillatory in nature, this being represented in the coordinate system in the form of a damping sine wave. The numerical value output of the computer indicates a high degree of stability if the value is close to or equals +1.0, or a high degree of instability if it is close to -1.0.

Thus if the numerical data obtained with the aid of the computer are plotted in a coordinate system as illustrated in the drawing, even during the first minutes of action of vestibular stimulation we can ascertain the disposition of the subject toward vertigo and discontinue application of the stimulus.

Application of the method of mathematical analysis of REG curves has made it possible to detect a number of new patterns in cerebral circulation under conditions of cumulative stimulation of the vestibular apparatus. This fact is of considerable importance primarily from the standpoint of clarifying the etiology and pathogenesis. The process of investigation can be considerably simplified by appropriate elaboration of the algorithm and training of the computer. It suffices for this purpose to introduce into the computer the data of measurement of no less than 5 REG curves at the beginning of action by the vestibular stimulant in order to obtain the requisite answer concerning displacements in circulation.

It is entirely possible at the present time to introduce the data of recorded physiological reactions directly into the computer. This substantially curtails the time required for processing the information obtained. The computer can also be used successfully in surgical procedures and during the postoperative period (V. M. Akhutin, A. P. Kolesov and coworkers, 1964; Stahl, 1965; Ledley, 1965; R. S. Dadashev et al., 1963, 1967; Pages, 1966).

The elements of the symptomatology of the state of cerebral circulation in response to vestibular stimulation have been obtained for the first time in our studies. They have proved to be similar to the data obtained by Yu. Ye. Moskalenko and coworkers (1971) as regards change in intracranial circulation under conditions of subjection to g-loads and weightlessness.

The principles of obtaining and processing physiological information presented in this paper may also be of broader significance: mathematical stimulation of the biological processes taking place in the organism can be accomplished by application of these principles, and in view of the availability of modern computers this may constitute a new stage in the development of medical science.

Findings

1. The rheoencephalographic method of investigating intracranial circulation makes it possible to obtain an objective dynamic characterization of the changes taking place in cerebral circulation in response to the action of cumulative coriolis forces. A substantial difference may be hereby detected

in the dynamics of cerebral circulation between individuals subject to vertigo /52
and those not subject to it.

2. The application of statistical analysis of the REG curve (discrete analysis) involving the preparation of Fourier series makes it possible to acquire more thorough and extensive information on cerebral circulation under conditions of stimulation of the vestibular apparatus.

3. A special interest for further application of the rheographic method in otorhinolaryngology is represented by evaluation of the significance of each of the coefficients of mathematical expression of the REG curves in study of the patterns of hemodynamics of the region of the body being examined.

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